Cancer Mortality Among Workers Exposed to Zinc Chromate Paints

Nancy A. Dalager, M.S.; Thomas J. Mason, Ph.D.; Joseph F. Fraumeni, Jr., M.D.; Robert Hoover, M.D.; and William W. Payne, Sc.D.

To evaluate the carcinogenicity of chromium compounds among user industries, the proportionate mortality experience of spray painters exposed to zinc chromate primer paints and electroplaters exposed to chromic acid in the aircraft maintenance industry was examined. Compared to the mortality patterns of U.S. white males, no excess of cancer was found in the 48 deaths among electroplaters. Analysis of the 202 deaths among spray painters revealed a significant excess of cancer, primarily of the respiratory tract. The relative increase of respiratory cancer showed a positive gradient with the length of estimated exposure time, and was confined to painters whose interval from first employment to death was at least 20 years. The findings are consistent with occupational exposure to chromium compounds, previously shown to be carcinogenic in manufacturing processes, but the effect of other paint constituents, tobacco smoking, or methodologic limitations could not be discounted.

Several studies have documented an excess risk of respiratory cancer among workers involved in the manufacture of chromium compounds.[1-8] The hazard has been identified in industries *producing* chromates from chromite ore and pigments from sodium dichromate, but only sparse data are available on the risk of cancer in occupational groups *using* chromium compounds. In the early 1930s the commercial development of zinc yellow (potassium zinc chromate) led to the widespread use of zinc chromate pigments as metal-protective primers, especially on aircraft.[9] This study examines the mortality experience of spray painters exposed to zinc chromate primer paints and electroplaters exposed to chromic acid in the aircraft maintenance industry.

From the Environmental Epidemiology Branch, National Cancer Institute, Bethesda, MD 20205 (Ms. Dalager and Drs. Mason, Fraumeni, and Hoover), and Frederick Cancer Research Center, Frederick, MD 21701 (Dr. Payne).

Presented at the 64th annual meeting of the American Occupational Medical Association, April 30 - May 4, 1979, in Anaheim, Calif.

Materials and Methods

The study population was derived from two large government-owned aircraft maintenance bases where spray painting utilized zinc chromate primer paint. At Base A, the civilian employment ranged from 21,000 to 22,000, with 150 painters. At Base B, the civilian employment was approximately 19,500, with 100 painters. Both bases had electroplating operations utilizing chromic acid. Maintenance work was performed in large, air-conditioned buildings at both bases. Planes were brought in periodically for a major overhaul during which the engines and other parts were removed, inspected, and repaired as needed, and the metal parts of the plane were cleaned and repainted. Painting was done in large booths which were closed on three sides. Painters usually worked in the booths without respirators, but a flow of air was maintained across the area in which the spraying was done. The exhaust was discharged through a curtain of water to remove the airborne paint before it entered the exhaust ducts. Some painting was done outside the booths on portions of the plane that could not be dismantled. The use of respirators varied in this setting. Metal surfaces were prepared for painting by painters' helpers. The primer paints used were primarily chromium-based compounds, especially zinc chromate, but starting in 1959 epoxy paints were used for some exterior surfaces. Repair and fabrication of fiberglass parts, which involved some grinding and sanding, were also carried on in the shops, but compared to the use of zinc chromate, these operations were relatively new.

The study was initiated in 1959 by one of the authors (W.W.P.), who obtained from the two bases the names of former employees exposed to the inhalation of zinc chromate paints and related chromium compounds. At each base, the service record card of every former employee was retained for ten years following termination. Information on this card included name, sex, date of birth, dates of employment at the plant, date of termination, and reason for termination. The study population

Reprinted from Journal of Occupational Medicine
January, 1980, Volume 22, No. 1
pp. 25-29

Table 1. — Employment Data for 202 Deaths Among White Male Painters.

Median year of first employment	1949
Median age at first employment	43 Years
Median duration from first to last employment	3.9 Years
Median duration from first employment to death	16.9 Years

consisted of 977 male painters and 276 male electroplaters.

The employees' names and social security numbers were periodically searched against the Social Security Administration files and Civil Service retirement records to identify those individuals on whom a death claim had been filed and the state in which the claim was filed. Copies of death certificates were requested from the state health departments. Underlying cause of death was classified by a trained nosologist according to the rules of the ICD revision in effect at the time of death and then recoded according to the 7th revision.[10] A computer file was generated on those workers for whom a death certificate had been obtained.

This analysis is based on deaths through 1977. Death certificates were obtained for 90% of the spray painters and 87% of the electroplaters for whom there was any indication of death. Those individuals whose death certificates could not be located were excluded from this analysis with the assumption that their causes of death were randomly distributed. Nonwhites were excluded because of the small number of deaths among them. The final study groups consisted of decedents who had worked either as painters or electroplaters for at least three months and terminated employment within ten years prior to July 31, 1959.

The relative frequency of specific causes of death in the study group was compared with "expected" numbers based on the mortality experience of the U.S. white male population. The expected numbers of deaths were determined by applying the cause-specific proportionate mortality of U.S. white males to the total numbers of deaths in the study group by five-year age groups and five-year time intervals.[11] Proportionate mortality ratios (PMRs) — observed/expected deaths — were calculated as measures of the relative difference between the observed and expected numbers for each cause of death. A summary chi-square test with one degree of freedom[12] was used to determine statistical significance.

The cause-specific PMRs appear to provide a reasonable estimate of the risk of fatal disease in an industrial group;[13,14] however, certain considerations must be kept in mind. The major assumption underlying a proportionate mortality analysis is that the study and comparison populations have the same mortality rate for all causes. In an occupational study, the overall mortality is frequently lower than that of the general population due to the "healthy worker effect."[15] In such situations, the PMRs for all cancer are often elevated due to a deficit in certain chronic diseases which prevent a person from working.

In recognition of the potential for a "healthy worker effect," proportionate cancer mortality ratios (PCMRs) have been calculated. PCMRs provide a better estimate of risk for specific cancer sites when the PMR for all cancer is artificially inflated by a deficit in other causes of death. Expected values were calculated using as a standard the proportionate cancer mortality for all U.S. white males. Expected values and PCMRs were also calculated using proportionate cancer mortality for white males residing in the particular county where the base is located. County-specific proportionate cancer mortality by five-year age groups was aggregated over two five-year time intervals, 1955-1959 and 1965-1969, and applied to those deaths occurring before or after January 1963.

Results

Only 48 deaths were seen among white male electroplaters, with no relative excess of cancer (10 deaths vs. 8.6 expected); thus no further analysis was made of this group.

Among the chromate-exposed painters there were 202 deaths. Employment information on this group is summarized in Table 1. Duration from first to last employment as a "painter" with the military provided an estimate of exposure to the zinc chromate pigments which were used extensively as a metal primer. The late median age of first employment (43 years) suggests that many painters may have received earlier occupational exposures for which there is no information.

Table 2. — Observed and Expected Deaths Due to Selected Causes, with Proportionate Mortality Ratios (PMR), Among White Male Painters

Underlying Cause of Death (ICD 7th Revision)	Observed Deaths	Expected Deaths*	PMR†
Malignant neoplasms (140-205)	50	36.9	1.36§
Respiratory cancers (160-164)	21	11.4	1.84‡
Cerebrovascular disease (330-334)	19	14.4	1.32
Cardiovascular disease (400-468)	79	90.9	0.87
Respiratory disease (470-527)	9	10.5	0.86
Digestive system disease (530-587)	12	10.0	1.20
Cirrhosis of the liver (581)	8	4.9	1.63
All external causes (800-998)	22	22.3	0.99
All other causes	11	17.0	0.65
All causes	202	202.0	1.00

* Expected values based on age-, time-, and cause-sepcific proportionate mortality for U.S. white males
† PMR = observed deaths/expected deaths
‡ Significant at the 0.01 level
§ Significant at the 0.05 level

Table 3. — Observed and Expected Deaths from Selected Cancer Sites, with Proportionate Mortality Ratios (PMR) and Proportionate Cancer Mortality Ratios (PCMR), Among White Male Painters.

Site (ICD 7th Revision)	Observed Deaths	Proportionate Mortality* Expected Deaths	PMR	Proportionate Cancer Mortality† Expected Deaths	PCMR
Buccal cavity & pharynx (140-148)	3	1.2	—	1.6	—
Digestive organs & peritoneum (150-159)	11	11.0	1.00	16.2	0.68
Respiratory system (160-164)	21	11.4	1.84‡	14.4	1.46
Brain & central nervous system (193)	3	1.2	—	1.6	—
Hodgkin's disease (201)	3	0.6	—	0.9	—
All other sites	9	11.5	0.78	15.3	0.59

* Expected values based on age-, time-, and cause-specific proportionate mortality for U.S. white males (PMR = observed deaths/expected deaths; not shown here when observed is less than 5)

† Expected values based on age-, time-, and site-specific proportionate cancer mortality for U.S. white males (PCMR = observed deaths/expected deaths; not shown here when observed is less than 5)

‡ Significant at the 0.01 level

The proportionate mortality experience of the painters is shown in Table 2. There was a significant excess of cancer, particularly of the respiratory tract. The PMRs were slightly elevated for cirrhosis of the liver and for cerebrovascular disease, and depressed for cardiovascular disease.

Table 3 presents the PMRs for selected cancer sites. The excess of respiratory cancer was confined to the lung (20 deaths vs. 10.7 expected). Although the relative frequency of digestive cancers was not high, there were five deaths from colon cancer compared to 3.3 expected. Increases were also seen for cancers of the oropharynx and the brain, and for Hodgkin's disease.

To evaluate the possibility that the relative excess of cancer simply reflects a deficit in mortality from other major causes, the expected deaths for selected cancer sites were recalculated (Table 3) using age-, time-, and site-specific proportionate *cancer* mortality for U.S. white males. This method assumes that the mortality rate for all cancers was equal in the study and the comparison populations, and compares the relative frequencies of specific sites. Using this more conservative approach, the expected number of deaths from respiratory cancer rose from 11.4 to 14.4. The observed to expected ratio was elevated but not significant (PCMR = 1.46). In addition, the PCMRs were high for cancers of the oropharynx and the brain, and for Hodgkin's disease; however, the PCMR for digestive cancer was depressed.

The best estimate available for duration of exposure was the time from first to last employment as a painter as recorded on the service record. This represented an overestimate of exposure time for those who did not have continuous service as a painter. A positive gradient in the ratios for respiratory cancer occurred with increasing length of employment (Table 4). The PMR was 3.0 for painters with the greatest time recorded, suggesting a dose-response relationship between exposure to zinc chromate paints and lung cancer. A similar gradient was observed for the PCMRs.

A "latency" effect was suggested when mortality from respiratory cancer was analyzed by the length of the interval between first employment and death (Table 5). A significant excess of respiratory cancer was confined to painters with 20 or more years between first employment and death (PMR = 2.75, $p < 0.01$; PCMR = 1.94, $p < 0.01$).

The PMRs for respiratory cancer were elevated for the 127 deaths from Base A and the 75 deaths from Base B, but only for Base A ($p < 0.01$) was the increase significant (Table 6). The PCMRs based on the cancer mortality experience of all U.S. white males showed a similar pattern to the PMRs by base but were not significant. To adjust for geographic variations in mortality, expected values were recalculated using age-, time-, and site-specific proportionate *cancer* mortality for white males residing in the same county as the particular base. The county-specific PCMR for respiratory cancer was significantly high for Base A ($p < 0.05$), but was not elevated for Base B.

To investigate the differences in the frequency of respiratory cancer at each base, the deaths were characterized according to available employment information. As shown in Table 7, the painters from Base A were

Table 4. — Observed to Expected Deaths from Respiratory Cancer, with Proportionate Mortality Ratios (PMR) and Proportionate Cancer Mortality Ratios (PCMR), Among White Male Painters.

Duration of Employment‡ (Years)	Observed Deaths	Proportionate Mortality* Expected Deaths	PMR	Proportionate Cancer Mortality† Expected Deaths	PCMR
< 5	9	6.4	1.41	7.2	1.25
5-9	6	3.0	2.00	4.0	1.50
10+	6	2.0	3.00§	3.2	1.88

* Expected values based on age-, time-, and cause-specific proportionate mortality for U.S. white males (PMR = observed deaths/expected deaths)

† Expected values based on age-, time-, and site-specific proportionate cancer mortality for U.S. white males (PCMR = observed deaths/expected deaths)

‡ Interval from first to last employment as a painter as indicated on the service record

§ Significant at the 0.01 level

Table 5. — Observed and Expected Deaths from Respiratory Cancer, with Proportionate Mortality Ratios (PMR) and Proportionate Cancer Mortality Ratios (PCMR), by Interval Between First Employment and Death Among White Male Painters.

Interval Between First Employment & Death (Years)	Observed Deaths	Proportionate Mortality*		Proportionate Cancer Mortality†	
		Expected Deaths	PMR	Expected Deaths	PCMR
< 10	2	2.0	—	3.2	—
10-19	5	4.4	1.14	4.0	1.25
20+	14	5.1	2.75‡	7.2	1.94‡

* Expected values based on age-, time-, and cause-specific proportionate mortality for U.S. white males (PMR = observed deaths/expected deaths; not shown here when observed is less than 5)

† Expected values based on age-, time-, and site-specific proportionate cancer mortality for U.S. white males (PCMR = observed deaths/expected deaths; not shown here when observed is less than 5)

‡ Significant at the 0.01 level

younger at first exposure than were the painters from Base B. At Base A 51.2% of the decedents had an interval of five years or more from first to last employment, compared to 33.3% at Base B. At Base A 43.3% of the decedents had an interval of at least 20 years from first exposure to death, compared to 30.7% at Base B.

Discussion

The limitations of a proportionate mortality analysis preclude any definitive statement concerning the risk of cancer among zinc chromate-exposed painters. As stated earlier, an elevated PMR for cancer may simply reflect a deficit in certain chronic diseases which prevent a person from working. However, an elevated PMR should be compared with other studies for consistency and may indicate that further investigation is warranted concerning the exposure of interest. The excess relative frequency of respiratory cancer among persons exposed during the spray painting of aircraft is consistent with three reports indicating an increased risk among workers producing chrome pigments.[6 7 8] In these studies, the exposures involved both lead and zinc chromates, although there was some suggestion that zinc pigments were especially hazardous.[8]

Information on cigarette smoking, the major risk factor for respiratory cancer, was not available on the painters. Painters are reported to smoke more heavily than the general male population,[16 17] and the elevated mortality ratio for cirrhosis in the present study group suggests excess alcohol consumption, which usually is correlated with smoking habits. In previous studies of chromate-induced cancer of the lung, the combined effect of smoking and of chromate exposure was not evaluated.[18]

Certain characteristics of the mortality ratios for respiratory cancer in the present study point to occupational exposures. In particular, the excess of respiratory cancer showed a positive gradient with the length of estimated exposure time, and was confined to painters whose interval from first employment to death was at least 20 years. Among painters dying of respiratory cancer, the estimated duration of exposure and the "latency" interval (first employment to death) were greater at Base A than at Base B. These differences probably account for the excess of respiratory cancer among painters at Base A only. There were no differences between installations in the type of paint used. Although chrome pigments are suspected carcinogens, it is not possible to exclude the effects of other paint constituents (e.g., solvents and synthetic resin carriers).

Painters in general are reported from occupational mortality statistics to be at excess risk of respiratory cancer,[19-22] although the responsible factors have not been clearly established. When the age-, race-, and sex-specific proportionate cancer mortality of painters from the state of Washington[20] was used to generate an expected value for painters at Base A, the proportionate cancer mortality ratio was elevated (1.27). This suggests that the risk of respiratory cancer among the zinc chromate-exposed painters may surpass the risk experienced by painters generally. Indeed, the ratio may be underestimated, since many painters in the Washington state survey could have worked in a large aircraft manufacturing plant where zinc chromate paints were used.

Table 6. — Observed to Expected Deaths from Respiratory Cancer with Proportionate Mortality Ratios (PMR) and Proportionate Cancer Mortality Ratios (PCMR), Among White Male Painters by Place of Employment.

	Observed Deaths	Proportionate Mortality*		Proportionate Cancer Mortality†		County-Specific Proportionate Cancer Mortality‡	
		Expected Deaths	PMR	Expected Deaths	PCMR	Expected Deaths	PCMR
Base A	15	7.1	2.11§	9.6	1.56	8.9	1.69¶
Base B	6	4.3	1.40	4.8	1.25	5.3	1.13

* Expected values based on age-, time-, and cause-specific proportionate mortality for U.S. white males (PMR = observed deaths/expected deaths)

† Expected values based on age-, time-, and site-specific proportionate cancer mortality for U.S. white males (PCMR = observed deaths/expected deaths)

‡ Expected values based on age-, time-, and site-specific proportionate cancer mortality for white males in the county of the particular base (PCMR = observed deaihs/expected deaths)

§ Significant at the 0.01 level

¶ Significant at the 0.05 level

Table 7. — Distribution of Deaths Among White Male Painters According to Age at First Exposure, Duration of Employment as a Painter,* and Interval Between First Exposure and Death, by Place of Employment.

		Base A		Base B	
		No.	%	No.	%
Age at first exposure (years)	< 40	55	43.3	21	28.0
	40-49	34	26.8	27	36.0
	50+	38	29.7	27	36.0
Duration of employment as a painter* (years)	< 5	62	48.8	50	66.7
	5-9	35	27.6	18	24.0
	10+	30	23.6	7	9.3
Interval between first employment & death (years)	< 10	26	20.5	20	26.7
	10-19	46	36.2	32	42.6
	20+	55	43.3	23	30.7
Total deaths		127		75	

*Interval from first to last employment as a painter as indicated on the service record

In summary, despite the limitations of this study, there appears to be an elevated risk of lung cancer among aircraft spray painters inhaling zinc chromate. The findings are consistent with preliminary studies in the chromium plating industry,[23,24] but there are more than one hundred occupational categories in which there is potential exposure to chromium compounds.[25] Although the risk of lung cancer has been established among workers involved in the manufacturing of chromates or the processing of chrome pigments, further studies are needed to clarify the carcinogenic hazard from exposure to chromium compounds in the user industries.

The authors wish to thank Aremita Watson and Rosalyn Weil for technical assistance and Deborah Waring for manuscript preparation.

References

1. Machle W and Gregorius F: Cancer of the respiratory system in the United States chromate-producing industry. *Public Health Rep* **63**:1114-1127, 1948.

2. Baetjer AM: Pulmonary carcinoma in chromate workers. I. A review of the literature and report of cases. *Arch Ind Hyg* **2**:487-516, 1950.

3. Mancuso RF and Hueper WC: Occupational cancer and other health hazards in a chromate plant: A medical appraisal. I. Lung cancer in chromate workers. *Ind Med Surg* **20**:358-363, 1951.

4. U.S. Public Health Service: Health of workers in chromate producing industry. Publication No. 192, U.S. Government Printing Office, Washington, D.C., 1953.

5. Bidstrup PL and Case RA: Carcinoma of the lung in workmen in the biochromates-producing industry in Great Britain. *Br J Ind Med* **13**:260-264, 1956.

6. Gross E and Kolsch F: Lung cancer in the chromate dye industry. *Arch Gewerbepathol Gewerbehyg* **12**:164-170, 1943.

7. Langard S and Norseth T: A cohort study of bronchial carcinomas in workers producing chromate pigments. *Br J Ind Med* **32**:62-65, 1975.

8. Davies JM: Lung-cancer mortality of workers making chrome pigments. *Lancet* **1**:384, 1978.

9. Calupski VH: The manufacture and properties of chromium pigments, in Chromium. Vol. I. Chemistry of Chromium and its Compounds. American Chemical Society Monograph #132, M. J. Udy (Ed.). New York: Reinhold Publishing Corporation, 1956, pp 357-384.

10. World Health Organization: Manual of the International Statistical Classification of Diseases, Injuries, and Causes of Death, Seventh Revision. Geneva: WHO, 1957.

11. Monson RR: Analysis of relative survival and proportional mortality. *Comput Biomed Res* 7:325-332, 1974.

12. Mantel N and Haenszel W: Statistical aspects of the analysis of data from retrospective studies. *J Natl Cancer Inst* **22**:719-748, 1959.

13. Decoufle P and Thomas TL: A methodological investigation of fatal disease risks in a large industrial cohort. *J Occup Med* **21**:107-110, 1979.

14. Kupper LL, McMichael AJ, Symans MJ, and Most BM: On the utility of proportional mortality analysis. *J Chronic Dis* **31**:15-22, 1978.

15. McMichael AJ, Haynes SG, and Tyroler HA: Observations on the evaluation of occupational mortality data. *J Occup Med* **17**:128-131, 1975.

16. Sterling TD and Weinkam JJ: Smoking characteristics by type of employment. *J Occup Med* **18**:743-754, 1976.

17. Friedman GB, Siegelaub AB, and Seltzer CC: Cigarette smoking and exposure to occupational hazards. *Am J Epidemiol* **98**:175-183, 1973.

18. Hoffmann D and Wynder EL: Smoking and occupational cancers. *Prev Med* **5**:245-261, 1976.

19. Menck HR and Henderson BE: Occupational differences in rates of lung cancer. *J Occup Med* **18**:797-801, 1976.

20. Milham S: Occupational mortality in Washington state, 1950-71. DHEW Pub. No. NIOSH 76-175-A,B,C, U.S. Government Printing Office, Washington, D.C., 1976.

21. The Registrar General's Dicennial Supplement, England and Wales, 1951. Occupational Mortality, Part II; Vol. 2, Tables. London: Her Majesty's Stationery Office, 1957.

22. The Registrar General's Dicennial Supplement, England and Wales, 1961. Occupational Mortality Tables. London: Her Majesty's Stationery Office, 1971.

23. Royle H: Toxicity of chromic acid in the chromium plating industry (1). *Environ Res* **10**:39-53, 1975.

24. Waterhouse JAH: Cancer among chromium platers. *Br J Cancer* **32**:262, 1975.

25. Milby TH, Key MM, Gibson RL, and Stokinger HE: Chemical hazards, in Occupational Diseases — A Guide to Their Recognition. PHS Pub. No. 1097, W. M. Gafafer (Ed.). U.S. Department of Health, Education and Welfare, Section IV, 1964, pp 120-122.